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Investment appraisal of a small, grid-connected photovoltaic plant under the Serbian feed-in tariff framework

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ABSTRACT

Serbian government has recently introduced the system of feed-in tariffs for electricity generated from renewable sources. The proposed feed-in tariff for photovoltaic electricity is set to 0.23 €/kWh paid for 12 years, with the PV electricity produced after the first 12 years being sold at the grid electricity market price for the rest of the plant lifetime. Although such FIT could have been justified by the small, average retail grid electricity price of just 0.054 €/kWh for Serbian households, the investment appraisal of a real case of 2.82 kWp PV power plant in two Serbian cities of Zlatibor and Negotin, clearly illustrates that the proposed FIT framework is not sufficient to attract investments into PV in Serbia. In the second part of the paper, we have analyzed alternative, more reasonable feed-in tarrif frameworks, with the goal of selecting those able to sustain the PV adoption and diffusion in Serbia.

Contents

1. Introduction

Following the ratification of the South-East European (SEE) Energy Community Treaty, which exists between EU and the countries of SEE, Serbian government accepted the obligation to apply Directive 2001/77/EC which promotes production of electricity from the renewable energy sources (RES) in 2006 [1]. Then, as one of the founders and member of the International Renewable Energy Agency (IRENA), Serbian government introduced the system of feed-in tariffs for RES electricity at the very end of 2009 [2,3]. Detailed overview of the legislation governing the feed-in tariff and RES energy in Serbia may be found in [4,5].

The feed-in tariff (FIT) paid for solar photovoltaic (PV) electricity in Serbia is fixed at 0.23 €/kWh for 12 years, with a total capacity of all PV power plants, for which FIT is to be provided, bounded to 5MW. Although this FIT amount may be deemed comparable to the recently reduced German variable FIT of 0.24–0.33 €/kWh for new PV installations [6,7], it is significantly smaller from FITs offered in some eastern European countries [8] such as:

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- Bulgaria—variable FIT, currently at 0.421 €/kWh for ≤5 kW plants, paid for 25 years,
- Slovenia—variable FIT, currently at 0.390 €/kWh for <50 kW plants, paid for 15 years,
- Slovakia—fixed FIT of 0.438 €/kWh paid for 12 years,
- Macedonia—fixed FIT of 0.30 €/kWh for <50 kW plants, paid for 20 years [9].

From the government's viewpoint, the low FIT for PV in Serbia could be easily justified by the small, government-controlled retail price of electricity—in average, it is just 0.054 €/kWh for households [10]. However, from the investor's viewpoint, this argument is useless, as the cost of PV power plant in Serbia is even higher than elsewhere in Europe, and the government does not provide any subsidies for its installation. Thus, if one of the goals of introducing FITs was to stimulate the installation of 5 MW of PV power plants in Serbia by 2012, as explicitly stated in Section 13.10 of [11], then the government must have used some nonstandard assumptions in determining the amount of FIT for PV.

Several economic models for determining an appropriate level of FIT for PV have been developed recently [12–15], however, they do not always take into account that the FIT period may be (considerably) shorter than the PV plant lifetime. Our goal here is to assess the proposed FIT for PV through a study of economical viability of an investment into a residential, grid-connected PV power plant in Serbia, under the following mild operating assumption:

> After the initial feed-in tariff period ends, all produced PV electricity will be bought at the market retail price (net-metering) during the plant's lifetime.

This assumption is, to some extent, supported by current Serbian FIT legislation—the FIT is governed by two separate decrees, where the one that establishes the amount of FIT for privileged producers [2] is valid until the end of 2012, while the other that establishes the requirements for becoming a privileged producer [3] is indefinite in nature. Thus, it is plausible to expect that once the investor's PV power plant obtains the status of the privileged producer, it retains that status throughout plant's lifetime.

Outline of the paper is as follows. The solar energy potential in Serbia, obtained from the global solar radiation measurements in Serbia during 1966–1988 [16,17], is reviewed in Section 2. An investment appraisal of a real case of residential, grid-connected PV plant is carried out in Section 3, clearly showing that the proposed FIT for PV is far from attractive and that the Serbian government should introduce further incentives for PV. Alternative, more reasonable feed-in tarrif level frameworks, with the goal of selecting those able to sustain the PV adoption and diffusion in Serbia, are analyzed in Section 4. Conclusions are given in Section 5.

2. Solar potential in Serbia

The solar radiation data collected by Yugoslav National Center for Solar Radiation during the period 1966–1988 [16,17] are used here. The measurements were ceased when Federal Hydrometeorological Institute of former Yugoslavia shut down the Center a few years prior to infamous turmoil period during the 1990s. Serbian Republic Hydrometeorological Service began to reestablish solar radiation measurements only at the end of 2009.

Fig. 1 shows the annual average of daily amount of solar energy falling on a horizontal surface in Serbia. The annual total solar radiation ranges from 1200 kWh/m^2 in northwestern parts to 1550 kWh/m^2 in southeastern parts of country. The monthly distribution of solar radiation in three representative cities is given in Table 1 and Fig. 2. It is found that the solar radiation is generally high throughout March–September.

Table 1
Average monthly global solar radiation on horizontal surface in kWh/m^2 in Zlatibor (western Serbia), Belgrade (capital) and Negotin (eastern Serbia).

Month	Zlatibor	Belgrade	Negotin
Jan	47	46	45
Feb	66	63	59
Mar	104	108	113
Apr	131	142	146
May	165	180	201
Jun	167	186	205
Jul	180	194	219
Aug	166	173	189
Sep	122	128	142
Oct	92	91	100
Nov	59	52	48
Dec	42	33	38
Total	1341	1396	1505

3. Overall investment appraisal of a real case

In this section a real residential PV power plant is proposed for two Serbian cities and financially analyzed using widely accepted investment appraisal methods. A 2.82 kWp PV power plant consists of 12 modules with nominal power 235 Wp and 14.3% efficiency, mounted on roof under 35° tilt angle, with an appropriate inverter having 95.5% efficiency. Estimate of the PV electricity generated during the first year of PV plant operation is obtained from simulations made with PVSYST 5.21 [18] for three Serbian cities—Belgrade (N44°48′, E20°28′, 132 m above sea level), Zlatibor (N43°44′, E19°43′, 1028 m above sea level) and Negotin (N44°14′, E22°33′, 42 m above sea level)—using the global solar radiation values from Table 1 and average monthly temperatures [19]. PVSYST generated synthetic hourly data based on these values. Simulations were performed with the option "Project design" using selected PV modules and inverter, and the results are given in Table 2.

The negligibly small difference between PV electricity produced in Zlatibor and Belgrade appears to be due to difference in PV losses due to temperature: −4.3% in Zlatibor and −7.0% in Belgrade, leading to higher performance ratio in Zlatibor. Thus, in the sequel we consider PV power plants installed in Zlatibor and Negotin only, with results for Zlatibor applying to Belgrade as well.

Retail price of monocrystalline PV modules in Serbia is about 3.2€/Wp. A residential 2.82 kWp PV power plant costs 9030€, while an inverter costs 1875€. Installation, mounting, metering devices and fees depend on the installation site, but these costs are estimated at around 1000€ in Serbia. Thus, the total upfront costs are estimated at 11905€.

PV module efficiency gradually decreases over time. Nowadays, PV modules have 25 years of guaranteed performance, at the end of which they will still produce at least 80% of nominal power, and this value is usually taken as system lifetime in literature. Here we assume annual degradation of PV module efficiency to be 0.88%, as this is approximately the largest value asserting manufacturer's 80% performance guarantee after 25 years. However, PV modules continue to produce electricity after the power output guarantee period as well, although with a lower performance. EPIA expects the guaranteed performance period to increase to 35 years [20], and European Commission expects PV systems will have a standard technical lifetime of up to 40 years by 2030 [21]. Based on these expectations, we assume here plant lifetime of 35 years, at the end of which PV system should still produce about 70% of nominal power.

Inverters transforming the direct current from PV modules into alternate current fed into the grid, have shorter lifetime from PV modules—between 10 and 12.5 years. It is plausible to assume that the proposed PV system will need three high quality inverters during its 35 years lifetime, one bought initially, another bought after

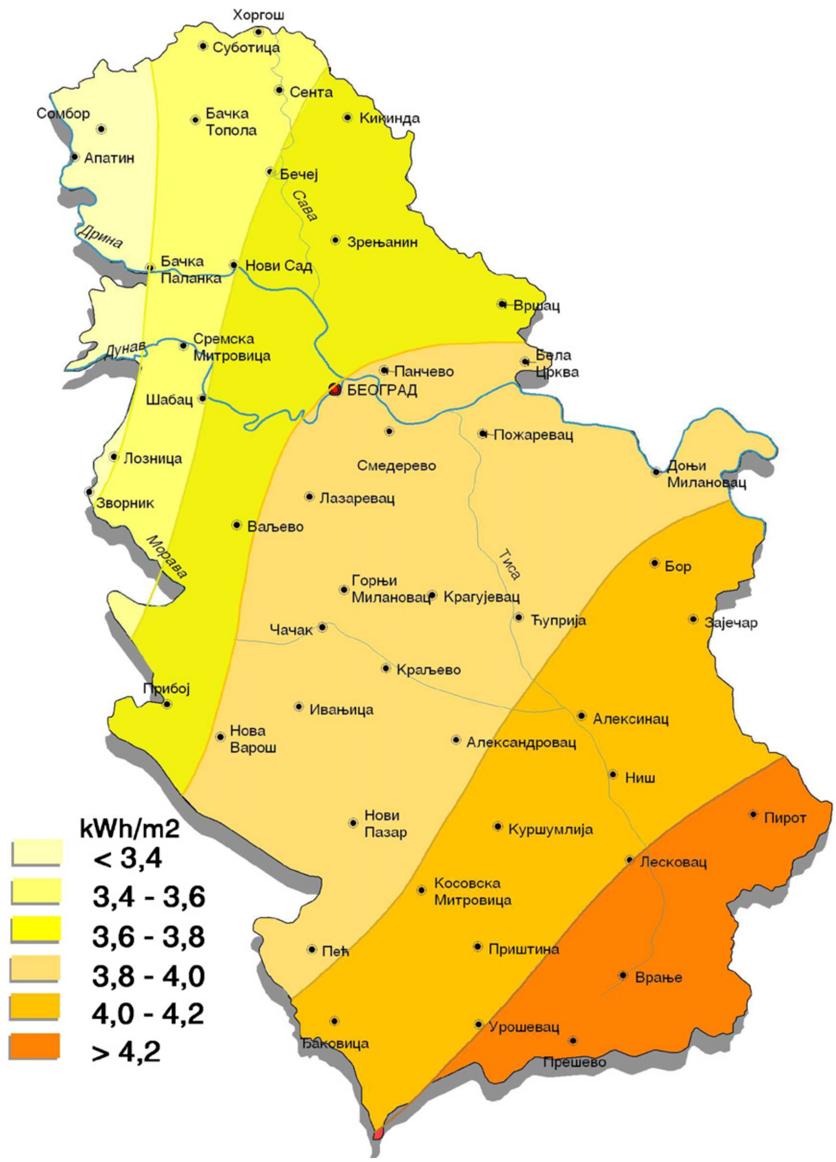

Fig. 1. Annual average of daily solar exposure in Serbia [16,17].

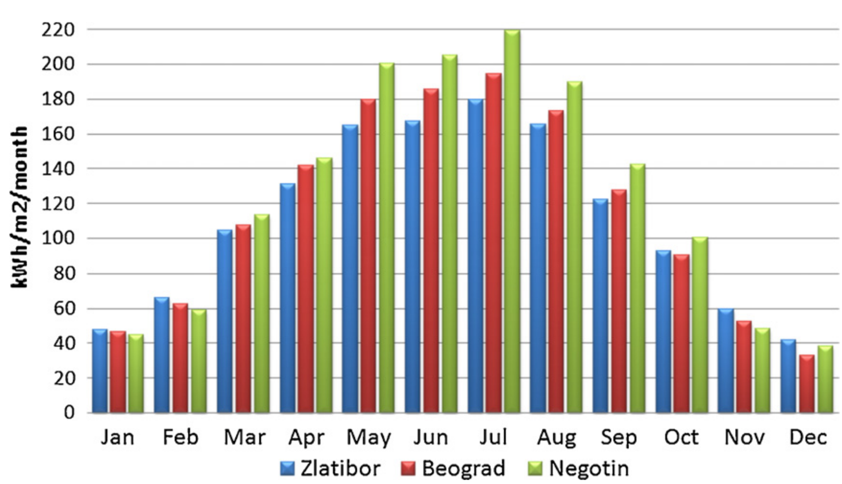

Fig. 2. Average monthly global solar radiation on horizontal surface in Zlatibor, Belgrade and Negotin.

Table 2
Results of PVSYST 5.21 simulations.

City	Annual solar radiation (kWh/m^2)	Electricity fed to the grid (kWh)	Performance ratio (%)
Zlatibor	1341	3519	80.8
Belgrade	1396	3514	78.6
Negotin	1505	3748	78.2

12 years and the third bought after 24 years. Further, it is expected that inverters will show a long term decline in price, annually between 2% [22] and 5% [15]. We have chosen more conservative value here.

Annual operation and maintenance costs are estimated to be 1% of the initial investment costs [21,23]. The operation and maintenance costs are expected to increase following a 4% rate [24].

After the initial feed-in period ends, it is assumed that the produced PV electricity is sold at the market price during the rest of the system lifetime. The Serbian government decree [3] implicitly supports this assumption by declaring that the privileged electric power producer has priority in selling the electricity. This privilege is indefinite in nature, and can be assumed throughout the PV system lifetime. Net-metering means that the owner is paid for excess PV electricity exported to the grid, however, for PV electricity spent within the household the owner makes savings on the grid electricity that would otherwise be paid at the market price. In order to keep the situation simple, it is assumed that the price paid for excess PV electricity exported to the grid is equal to the grid electricity price.

Current average grid electricity price for households in Serbia is 0.054€, and the annual averages (in € cents) from 2002 to 2011 [10] are presented in Fig. 3. An apparently unusual fact that the electricity price has went down several times may be attributed to the fluctuating exchange rate between Serbian dinars and €, as well as the government policy on treating grid electricity price as a socioeconomic category [25]. Linear trend of 7.25% increase can be observed over this period, and this value is used as future annual grid electricity price escalation rate.

In Tables 3 and 4 all data needed for the investment appraisal of PV power plants installed in Zlatibor and Negotin during a 35-year period are reported. Column A contains investment costs—total upfront costs of PV power plant installation, and costs of change of inverter after 12 and 24 years of operation. Column B contains positive cash flows from feed-in tariff during the first 12 years of operation, while column C contains positive cash flows from net metering after the initial feed-in tariff period ends. We have included additional data in columns B and C, written in light gray, which represent potential positive cash flows in cases that the feed-in tariff is prolonged after 12 years (in column B) or that net-metering starts from the first year (in column C). This data will be useful in next section when we discuss alternative feed-in tariff frameworks. Column D contains operation and maintenance costs,

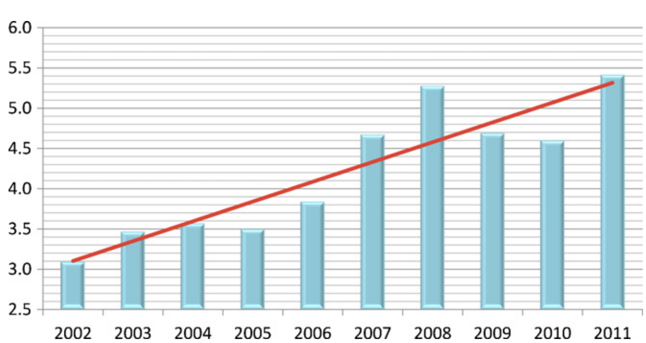

Fig. 3. Average grid electricity price for Serbian households from 2002 to 2011 in € cents.

while the last column gives total cash flows in a given year. All values are rounded to the nearest integer. In order to evaluate the profitability and the economic aspects of PV power plant installation, we use the following widely accepted investment appraisal methods [26,27]: the net present value, the payback time and the internal rate of return.

3.1. Net present value

The net present value (NPV) of a time series of cash flows is a most accepted standard method in the appraisal of long-term projects. It uses the real interest rate, or the discount rate, to discount each future cash flow to its present value, whose sum then gives the net present value:

$$\mathrm{NPV} = -I_0 + \sum_{i=1}^{n} \frac{\mathrm{CF}_i}{(1+r)^i}.$$

In the formula above, I_0 is the initial investment, n is the project lifetime in years, CF_i is the (positive or negative) net cash flow during year i, and r is the discount rate. In general, NPV is indicative of the value obtained by investing in a project, and the project could be accepted if NPV > 0.

The real interest rate r used to discount future cash flows is a key variable, whose choice significantly affects the net present value. Since it is impossible to predict trends in economy with enough certainty, the real interest rate is often chosen as the rate, which the capital needed for a project would return if invested in a financial asset with similar duration and similar probability of default at the date of calculation, plus an adequate risk premium. In our example, a 15-year, €-denominated Treasury bond, issued by the Public Debt Administration of the Serbian Ministry of Finance [28], may be considered as an adequate alternative investment, since both feed-in tariff and coupon interests are similar Government's promises and, thus, are assumed to have the same probability of default. The bonds have semi-annual payments with coupon rate of 5.85% before 10% tax, so that we may assume 5.32% to be the government-guaranteed real interest rate r.

A rigorous approach of accounting for risk factors would require to first explicitly identify and evaluate risks for PV power plants (lightning damage and overvoltage [29], hailstorms, etc.), and then adjust the cash flows with the estimated probability of occurrence of risk factors, before discounting. An often used alternative way of adjusting for risk factors simply adds a risk premium to the discount rate. Although this is not entirely valid approach, and is subject to criticism, it can still provide a reasonable approximation to risk evaluation. In our example, we will assume a risk premium of up to 50% of the risk-free rate r, so that the real interest rate will range between 5.32% and 7.98%.

Fig. 4 shows the net present value (in €) of PV power plants in Zlatibor and Negotin, for a range of feasible discount rates. For the risk-free discount rate of r = 5.32%, the *NPV* of PV power plant is −4342€ in Zlatibor and −3568€ in Negotin, while for the risk-adjusted discount rate of r = 7.98%, the *NPV* is −6154€ in Zlatibor and −5587€ in Negotin. Apparently, with negative *NPV*, ranging between 30% and 52% of the total upfront costs, the investment in PV power plants in Serbia should not be accepted under present FIT framework.

Table 3
Cash-flow forecasts for the 2.82 kWp PV plant in Zlatibor.

Year	A Investment (€)	B Cash-flow from feed-in tariff (€0.23 × production)	C Cash-flow from net-metering (grid electricity price × production) (€)	D Operation and maintenance costs (€)	Total cash-flows (€)
0	−11905				−11905
1		809	190	−119	690
2		802	202	−124	678
3		795	215	−129	666
4		788	228	−134	654
5		781	243	−139	642
6		774	258	−145	630
7		768	274	−151	617
8		761	292	−157	604
9		754	310	−163	591
10		747	329	−169	578
11		741	350	−176	565
12	−1471	734	372	−183	−920
13		728	396	−191	205
14		722	421	−198	223
15		715	447	−206	241
16		709	476	−214	261
17		703	506	−223	283
18		696	537	−232	306
19		690	571	−241	330
20		684	607	−251	357
21		678	646	−261	385
22		672	686	−271	415
23		666	730	−282	488
24	−1155	660	776	−293	−672
25		655	825	−305	520
26		649	877	−317	559
27		643	932	−330	602
28		638	991	−343	647
29		632	1053	−357	696
30		626	1119	−371	748
31		621	1190	−386	804
32		615	1265	−401	864
33		610	1345	−417	927
34		605	1430	−434	996
35		599	1520	−452	1068

3.2. Payback time

The simple payback time refers to the number of years needed for cumulative cash-flows to cover the initial investment costs. It is widely used as an investment appraisal method, as it easy to apply and understand, regardless of the fact that it does not take into account the cash-flows after the payback time. In our example, the cumulative cash flows for PV power plants in Zlatibor and Negotin are obtained by summing total annual cash flows (the last column) from Tables 3 and 4, and they are displayed in Fig. 5. The payback time of PV power plant is 30 years in Zlatibor and 28 years in Negotin, which is very close to the plant lifetime.

The simple payback time has further limitations for its use, as it ignores the time value of money, opportunity cost of capital, and risks. This can be rectified by discounting future cash-flows to present time using the real interest rate, and defining the discounted payback time as the number of years needed for cumulative discounted cash-flows to cover the initial investment costs. In our example, however, the discounted payback time

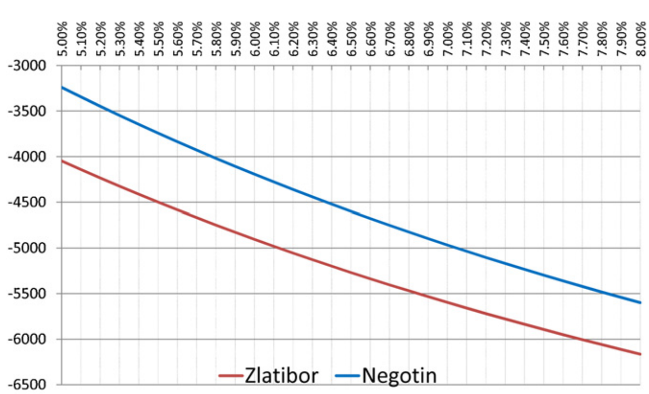

Fig. 4. Net present value (in €) of PV power plants in Zlatibor and Negotin for real interest rates between 5% and 8%.

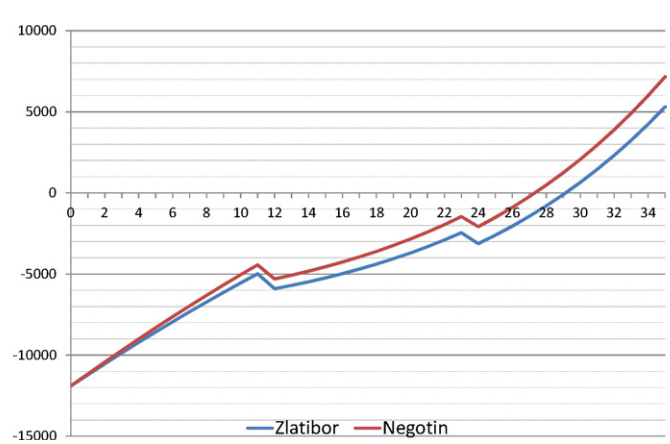

Fig. 5. Cumulative cash flows (in €) of PV power plants in Zlatibor and Negotin during their lifetime.

Table 4
Cash-flow forecasts for the 2.82 kWp PV plant in Negotin.

Year	A Investment (€)	B Cash-flow from feed-in tariff (€0.23 × production)	C Cash-flow from net-metering (grid electricity price × production) (€)	D Operation and maintenance costs (€)	Total cash-flows (€)
0	−11905				−11905
1		862	202	−119	743
2		854	215	−124	731
3		847	229	−129	718
4		839	243	−134	706
5		832	258	−139	693
6		825	275	−145	680
7		818	292	−151	667
8		810	311	−157	654
9		803	330	−163	640
10		796	351	−169	627
11		789	373	−176	613
12	−1471	782	397	−183	−872
13		775	422	−191	231
14		768	448	−198	250
15		762	476	−206	270
16		755	506	−214	292
17		748	538	−223	316
18		742	572	−232	341
19		735	608	−241	367
20		729	647	−251	396
21		722	688	−261	427
22		716	731	−271	460
23		710	777	−282	495
24	−1155	703	826	−293	−622
25		697	878	−305	573
26		691	934	−317	616
27		685	992	−330	663
28		679	1055	−343	712
29		673	1122	−357	765
30		667	1192	−371	821
31		661	1268	−386	882
32		655	1347	−401	946
33		650	1432	−417	1015
34		644	1523	−434	1089
35		638	1619	−452	1167

may be consider as infinite, since the net present value of PV power plants in Zlatibor and Negotin is negative over the system lifetime.

3.3. Internal rate of return

One of the issues with the net present value is its dependence on the real interest rate, which can easily change in future. The third widely accepted investment appraisal method, which avoids the assessment of the real interest rate, is the internal rate of return (IRR). The IRR is defined as that discount rate r which yields NPV=0, i.e., r is a solution of equation

$$-I_0 + \sum_{i=1}^{n} \frac{\mathrm{CF}_i}{(1+r)^i} = 0.$$

Thus, the IRR represents the maximum interest rate allowed for accepting the investment. If IRR is larger than the opportunity cost of capital (or real interest rate), the PV power plant will gain profits and the investment may be accepted. As a rule of thumb, an investment is considered to be profitable in literature if its IRR is 10%. On the other hand, if IRR is smaller than the opportunity cost of capital, the PV power plant will acquire losses and the investment should not be accepted.

In our example, PV power plant in Zlatibor has IRR of 2.06% and PV power plant in Negotin has IRR of 2.70%, both of which are significantly smaller than the real interest rate.

4. Proposals for more reasonable PV incentives in Serbia

As we see from the previous section, all three investment appraisal methods—the net present value, the payback time and the internal rate of return—suggest that the Serbian current PV feed-in tariff framework is not profitable and, thus, unable to raise interest in PV adoption and diffusion among investors and homeowners in Serbia.

Here we are interested in discussing alternative, more reasonable PV incentives that are based on, or include the current FIT framework. Firstly, the negative net present value, discussed in Section 3.1, suggests that the cash flows from FIT should be enlarged, either through the larger FIT amount per kWh or through the longer period of time during which FIT is paid. Secondly, the fact that the internal rate of return, discussed in Section 3.3, is positive (between 2.06% and 2.70%) suggests that the PV power plants might become profitable if the total upfront costs would be covered from the government-issued PV loan with interest rate smaller than 2%. At the end, we also study a scenario in which FIT is kept proportional to the grid electricity price and paid during the plant lifetime. Each of these alternatives is discussed and appraised in the following subsections.

4.1. Larger FIT amount paid for 12 years

Here we consider that the constant FIT amount is being paid for 12 years, after which period the net-metering is used for the rest of 35-year lifetime. Table 5 contains the net present value of PV power plants in Zlatibor and Negotin for FIT amounts between

Table 5
The net present values of PV power plants in Zlatibor and Negotin for different amounts of feed-in tariff paid for 12 years.

FIT amount (€)	Discount rate 5.32%		Discount rate 7.98%	
	NPV in Zlatibor (€)	NPV in Negotin (€)	NPV in Zlatibor (€)	NPV in Negotin (€)
0.23	−4342	−3568	−6154	−5587
0.24	−4049	−3255	−5899	−5316
0.25	−3755	−2942	−5644	−5044
0.26	−3462	−2630	−5389	−4773
0.27	−3168	−2317	−5134	−4501
0.28	−2875	−2004	−4879	−4229
0.29	−2581	−1692	−4624	−3958
0.30	−2287	−1379	−4369	−3686
0.31	−1994	−1067	−4114	−3415
0.32	−1700	−754	−3859	−3143
0.33	−1407	−441	−3604	−2871
0.34	−1113	−129	−3349	−2600
0.35	−820	184	−3094	−2328
0.36	−526	497	−2839	−2057
0.37	−233	809	−2584	−1785
0.38	61	1122	−2329	−1513
0.39	354	1435	−2074	−1242
0.40	648	1747	−1819	−970
0.41	941	2060	−1564	−698
0.42	1235	2372	−1309	−427
0.43	1528	2685	−1054	−155
0.44	1822	2998	−799	116
0.45	2115	3310	−544	388
0.46	2409	3623	−289	660
0.47	2703	3936	−34	931
0.48	2996	4248	221	1203
0.49	3290	4561	476	1474
0.50	3583	4873	731	1746
0.51	3877	5186	986	2018
0.52	4170	5499	1241	2289
0.53	4464	5811	1496	2561
0.54	4757	6124	1751	2832
0.55	5051	6437	2006	3104

0.23€ and 0.55€, given in the first column. The second and the third column contain the NPV of PV power plants in Zlatibor and Negotin, respectively, for the risk-free discount rate of 5.32%. The fourth and the fifth column contain the NPV of PV power plants in Zlatibor and Negotin, respectively, for the risk-adjusted discount rate of 7.98%.

As evident from Table 5, if the risk-free discount rate of 5.32% is assumed, PV power plants in Zlatibor and Negotin begin to yield positive NPV for FIT amounts of at least 0.38€ and 0.35€, respectively. On the other hand, if the risk-adjusted discount rate of 7.98% is assumed, PV power plants in Zlatibor and Negotin begin to yield positive NPV only for much larger FIT amounts of at least 0.48€ and 0.44€, respectively.

However, these particular FIT amounts yield a very modest NPV, which cannot be considered profitable. The internal rate of return of the total annual cash-flows of PV power plants in Zlatibor and Negotin, for FIT amounts between 0.23€ and 0.55€, is presented in Fig. 6. The IRR of 10% for PV power plant in Zlatibor is obtained for FIT amount of 0.535€, while the IRR of 10% for PV power plant in Negotin is obtained for FIT amount of 0.497€. Thus, in order for investments into PV power plants in Serbia to be considered profitable, the FIT amount, paid for 12 years, has to be raised to at least 0.50 €/kWh. However, for the FIT amount set to 0.50 €/kWh, the discounted payback time turns out to be very sensitive to the discount rate for a plant in Zlatibor: when the discount rate

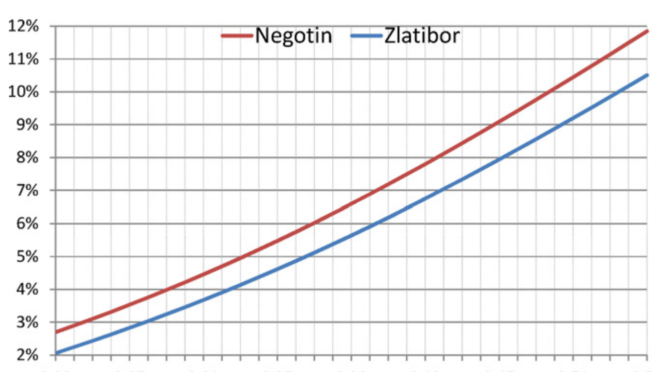

Fig. 6. Internal rate of return of PV power plants in Zlatibor and Negotin for FIT amounts between 0.23€ and 0.55€ paid for 12 years.

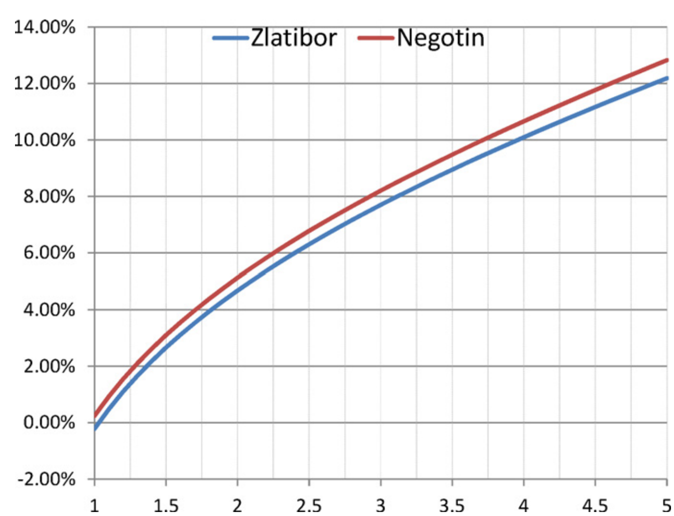

Fig. 7. Internal rate of return of PV power plants in Zlatibor and Negotin for FIT being is equal to c times the grid electricity price during plant lifetime.

Table 6
The net present values of PV power plants in Zlatibor and Negotin for different FIT periods.

FIT period (years)	Discount rate 5.32%		Discount rate 7.98%	
	NPV in Zlatibor (€)	NPV in Negotin (€)	NPV in Zlatibor (€)	NPV in Negotin (€)
12	−4342	−3568	−6154	−5587
13	−4173	−3387	−6032	−5457
14	−4027	−3232	−5929	−5348
15	−3904	−3101	−5844	−5258
16	−3802	−2993	−5776	−5185
17	−3721	−2906	−5723	−5128
18	−3658	−2839	−5683	−5085
19	−3614	−2792	−5655	−5056
20	−3586	−2763	−5638	−5038
21	−3576	−2751	−5632	−5031

Table 7
The internal rate of return on investment in PV power plant in Zlatibor, with government-backed PV loan covering a part of total upfront costs.

Investor (% of costs)	PV loan (% of costs)	PV loan rate				
		0%	0.5%	1%	1.5%	2%
10	90	24.63%	20.38%	14.48%	6.91%	2.44%
15	85	13.29%	10.47%	7.52%	4.75%	2.32%
20	80	9.09%	7.40%	5.67%	3.94%	2.25%
25	75	7.11%	5.95%	4.73%	3.48%	2.21%
30	70	5.94%	5.06%	4.14%	3.18%	2.18%
40	60	4.56%	4.01%	3.42%	2.80%	2.14%
50	50	3.75%	3.38%	2.98%	2.56%	2.11%

increases from 5.32% to 7.98%, the discounted payback time of a plant in Zlatibor increases from 11 to 23 years! Thus, it is far more reasonable to accept slightly higher FIT amount of 0.53 €/kWh, for which the discounted payback time is from 10 to 13 years in Zlatibor, and from 9 to 10 years in Negotin, for the discount rate ranging between 5.32% and 7.98%.

4.2. FIT of 0.23€ paid for a longer period of time

Here we consider that the FIT of 0.23€ is being paid for a certain number of years, after which period the net-metering is used for the rest of 35-year lifetime. From the cash-flows shown in gray in Tables 3 and 4, we can see that the longest reasonable FIT period is 21 years, as the net-metering starts to yield larger cash-flows than the FIT afterwards. Table 6 contains the net present value of PV power plants in Zlatibor and Negotin for FIT periods between 12 and 21 years, given in the first column. The second and the third column contain the NPV of PV power plants in Zlatibor and Negotin, respectively, for the risk-free discount rate of 5.32%, while the fourth and the fifth column contain the NPV of PV power plants in Zlatibor and Negotin, respectively, for the risk-adjusted discount rate of 7.98%.

As evident from Table 6, the net present value remains negative regardless of the FIT period. The internal rate of return for PV power plant in Zlatibor range from 2.06% for FIT period of 12 years to 2.69% for FIT period of 21 years, while the internal rate of return for PV power plant in Negotin range from 2.70% for FIT period of 12 years to 3.34% for FIT period of 21 years, all of which are still significantly lower than the real interest rate.

4.3. Low-rate PV loan repaid during plant lifetime

Since the internal rate of return of the real case of PV power plant in both Zlatibor and Negotin is larger than 2% (see Section 3.3), it follows that the investment may become profitable if the government would give a low-rate, equated-payment PV loan to investor aimed to cover a part of total upfront costs of PV power plant installation, while keeping the proposed feed-in tariff framework. In order to lower the payments and make investment profitable, it is assumed that the payment period is equal to the plant lifetime. Thus, in this scenario, an investor willing to install a PV power plant in Serbia would cover a part of initial costs himself, with the rest of the initial costs covered from PV loan with interest rate less than 2%. The investor would be paid FIT of 0.23 €/kWh for the first 12 years, after which the produced electricity would be net-metered for the next 23 years, while the investor would be repaying PV loan during the whole 35 years. Tables 7 and 8 contain the internal rates of return for investor's annual cash-flows from PV power plant in Zlatibor and Negotin, respectively, for investor covering from 10% to 50% of total upfront costs and PV loan rate from 0% to 2%.

It is evident from these tables that, in this scenario, the investment into PV power plant in Serbia may become profitable only if the government covers at least 80% of the total upfront costs, but even then only if PV loan rate is set below 1%. However, this option

Table 8
The internal rate of return on investment in PV power plant in Negotin, with government-backed PV loan covering a part of total upfront costs.

Investor (% of costs)	PV loan (% of costs)	PV loan rate				
		0%	0.5%	1%	1.5%	2%
10	90	30.90%	27.50%	23.47%	18.23%	10.44%
15	85	18.03%	15.49%	12.61%	9.46%	6.36%
20	80	12.33%	10.65%	8.86%	7.02%	5.17%
25	75	9.51%	8.35%	7.12%	5.85%	4.54%
30	70	7.86%	7.00%	6.09%	5.13%	4.14%
40	60	5.98%	5.44%	4.87%	4.27%	3.63%
50	50	4.90%	4.54%	4.16%	3.75%	3.33%

Table 9
The investment appraisal indicators of PV power plants in Zlatibor and Negotin for FIT escalating at the same rate as the grid electricity price, with initial FIT being equal to 0.21 €/kWh.

Appraisal indicator	Discount rate 5.32%		Discount rate 7.98%	
	PV plant in Zlatibor	PV plant in Negotin	PV plant in Zlatibor	PV plant in Negotin
Net present value	12 657€	14 538€	3 736€	4 946€
Discounted payback time	20 years	18 years	26 years	24 years
Internal rate of return	9.85%	10.41%	9.85%	10.41%

is not realistic, as such kind of PV loan would put too large financial burden on the government immediately.

4.4. Escalating FIT paid during plant lifetime

Singh and Singh in [30] have introduced a new method for determining generating cost of photovoltaic electricity, the basic premise of which is that the cost of PV electricity should increase at the same rate as the cost of grid electricity. Translated to our example, this premise yields the scenario in which the investor fully covers the costs of installing PV power plant, and in return receives FIT with annual escalation rate of 7.25% during the plant's 35-year lifetime.

Let c be the constant ratio between FIT and the grid electricity price per kWh. The total annual cash-flows for PV power plants in Zlatibor and Negotin in this case are obtained by summing the values in columns A, D and c times the column C from Tables 3 and 4, respectively. The internal rate of return of PV power plants in Zlatibor and Negotin, for the risk-free discount rate of 5.32% and the risk-adjusted discount rate of 7.98%, is shown in Fig. 7. The values of the ratio c range between 1, when FIT is equal to the grid electricity price, and 5, when FIT in the first year is equal to 0.27€.

We see from Fig. 7 that, in this scenario, the internal rates of return do not differ much in Zlatibor and Negotin, and that the investment may be considered profitable at both locations if the ratio between FIT and the grid electricity price is set to 3.9, or, in other words, FIT in the first year is set to 0.21 €/kWh. The net present value, the discounted payback time and the internal rate of return of PV power plant in Zlatibor and Negotin for initial FIT equal to 0.21 €/kWh are shown in Table 9 for both risk-free and risk-adjusted discount rates. Although the net present value is significantly higher in this case than in the case of constant FIT of 0.53 €/kWh paid for 12 years (see Section 4.1), it has to be observed that it is compensated by longer discounted payback time, which in this case is twice as long as that for constant FIT.

5. Conclusions

Photovoltaics should be strongly promoted in countries with higher annual average solar radiation, such as Serbia, and in that direction, the Serbian government has introduced the feed-in tariff for PV, in the amount of 0.23 €/kWh paid for 12 years, with the option of net-metering the PV electricity produced after the first 12 years. However, the investment appraisal of a real case of 2.82 kWp PV power plant installed in Zlatibor and Negotin, clearly shows that the proposed FIT framework is far from being profitable.

Among the alternative FIT frameworks further analyzed, the following two options show the potential for sustaining PV adoption and diffusion in Serbia:

- the constant FIT of 0.53 €/kWh paid for 12 years, following by net-metering the electricity produced after the first 12 years, and
- the escalating FIT paid during the plant lifetime, initially set to 0.21 €/kWh, and escalating at the same rate as the grid electricity price.

The first option has lower net present value and the discounted payback time between 9 and 13 years, depending on the location and the discount rate, and it puts larger financial commitment on the government during the first 12 years. Although the second option yields higher net present value, its discounted payback time is twice longer—between 18 and 26 years, and it more evenly distributes (the net present value of) the financial commitment of the government throughout the PV power plant lifetime. Thus, the second option may be considered a more reasonable choice for the government aiming at supporting installation of 5MWp of PV power plants in Serbia, as explicitly stated in Section 13.10 of [11].

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References

[1] Mihajlov A. Opportunities and challenges for a sustainable energy policy in SE Europe: SE European Energy Community Treaty. Renewable and Sustainable Energy Reviews 2010;14:872–5.
[2] Decree on measures of incentives for the production of electricity using renewable energy sources and combined electric and thermal power. Government of the Republic of Serbia. Official Gazette RS 72/09.
[3] Decree on the requirements for obtaining the status of the privileged electric power producer and the criteria for assessing fulfilment of these requirements. Government of the Republic of Serbia. Official Gazette RS 99/09.
[4] Tešić M, Kiss F, Zavargo Z. Renewable energy policy in the Republic of Serbia. Renewable and Sustainable Energy Reviews 2011;15:752–8.
[5] Djurdjević D. Perspectives and assessments of solar PV power engineering in the Republic of Serbia. Renewable and Sustainable Energy Reviews 2011;15:2431–46.
[6] Lang M, Mutschler U. German Solar Feed-in tariff reduction Mid-2010, German Energy Blog, http://www.germanenergyblog.de/?page_id=2740 [accessed Sep. 2010].
[7] Erstes Gesatz zur Änderung des Erneuerbare-Energien-Gesetzes, vom 11. August 2010, Bundestag, Bundesgesetzblatt Jahrgang 2010, Teil I, Nr. 43, 1170-1172, available in German at http://www.bundesgerichtshof.de/DE/Bibliothek/GesMat/WP17/E/eeg.html [accessed Sep. 2010].
[8] Dusonchet L, Telaretti E. Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in eastern European Union countries. Energy Policy 2010;38:4011–20.
[9] Decision on determination of feed in tariff for purchase/sale electricity produced for photovoltaic power system (in Macedonian). Energy Regulatory Commission of Macedonia, http://www.erc.org.mk/Uploads/EE-C-2010.07.27-ODLUKA%20POVLASTENATARIFA%20EE%20OD%20FOTOVOLTAICI%20-%20GS%5B1%5D.pdf [accessed Oct. 2010].
[10] Annual report for the year 2009, http://www.eps.rs/Eng/Godisnji%20Izvestaji/ENG%202009%20web1.pdf. Technical report for the year 2009, http://www.eps.rs/Eng/Tehnicki%20Izvestaji/EPS_Tehncki_Godisnjak2009_en_web.pdf. The price list for electricity sale for tariff buyers http://www.eps.rs/Eng/Article.aspx?lista=Sitemap&id=21. Annual report for the year 2008, http://www.eps.rs/Eng/Godisnji%20Izvestaji/EPS%20Annual%20report%202008.pdf. Annual report for the year 2006. http://www.eps.rs/GodisnjiIzvestaji/2006AR2SLow.pdf, Electric Power Industry of Serbia [accessed Sep. 2010].
[11] Decree on Amendments and Supplements to the Decree on Program for the Realization of the Energy Sector Development Strategy of the Republic of Serbia until 2015, for the period 2007-2012, Government of the Republic of Serbia, Official Gazette RS 72/09, available online in English at http://www.ssl-link.com/mre/cms/mestoZaUploadFajlove/POS_OIE_2009_eng_-_OJ_99-2009.pdf [accessed Sep. 2010].

[12] Zahedi A. Development of an economical model to determine an appropriate feed-in tariff for grid-connected solar PV electricity in all states of Australia. Renewable and Sustainable Energy Reviews 2009;13:871–8.
[13] Ayompe LM, Duffy A, McCormack SJ, Conlon M. Projected costs of a grid-connected domestic PV system under different scenarios in Ireland, using measured data from a trial installation. Energy Policy 2010;38: 3731–43.
[14] Bhandari R, Stadler I. Grid parity analysis of solar photovoltaic systems in Germany using experience curves. Solar Energy 2009;83:1634–44.
[15] Rigter J, Vidican G. Cost and optimal feed-in tariff for small scale photovoltaic systems in China. Energy Policy 2010;38:6989–7000.
[16] Study of the energy potential of Serbia for the use of solar radiation and wind energy. Institute for Multidisciplinary Studies of the University of Belgrade, No. EE704-1052A, Belgrade; 2004.
[17] Gburčik V. Final report of the technological development Project TD-7042B "Atlas of solar and wind energy potential in Serbia". Institute of Multidisciplinary Research of the University of Belgrade, Belgrade; 2008.
[18] Mermoud A, Lejeune T, Ineichen P, Perrinjaquet L. PVSYST 5.21–study of photovoltaic systems. Institute for the Sciences of the Environment, Group of Energy, University of Geneva, http://www.pvsyst.com.
[19] 30 year averages, Republic Hydrometeorological Service of Serbia, http://www.hidmet.gov.rs/eng/meteorologija/klimatologija_srednjaci.php.
[20] Solar Generation V-2008. Solar electricity for over one billion people and two million jobs by 2020. European Photovoltaic Industry Association, available online at http://www.epia.org/publications/epia-publications.html [accessed Sep. 2010].
[21] A vision for photovoltaic technology. Luxemburg: European commission, Publication Office; 2005.
[22] Borenstein S. Electricity rate structures and the economics of solar PV: could mandatory time-of-use rates undermine California's solar photovoltaic subsidies? Center for the Study of Energy Markets, University of California Energy Institute, UC Berkeley; 2007.
[23] Koner PK, Dutta V, Chopra KL. A comparative life cycle energy cost analysis of photovoltaic and fuel generator for load shedding application. Solar Energy Materials and Solar Cells 2000;60:309–22.
[24] Focacci A. Residential plants investment appraisal subsequent to the new supporting photovoltaic economic mechanism in Italy. Renewable and Sustainable Energy Reviews 2009;13:2710–5.
[25] Stevanović S, Pucar M, Kosorić V. Potential solar energy use in a residential district in Niš. SPATIUM International Review 2009;20:9–18.
[26] Khan MY. Theory & problems in financial management. Boston: McGraw Hill Higher Education; 1993.
[27] Feibel BJ. Investment performance management. New York: Wiley; 2003.
[28] Auction schedule for Euro denominated securities for Q2, 2011, Public Debt Administration, Ministry of Finance of Serbia, http://www.mfin.gov.rs/UserFiles/File/Uprave/Uprava%20za%20javni%20dug/2011%20maj/Scheduale%20Q2%20-%20euro%20denominated%2006%2005%202011.pdf [accessed Nov. 2011].
[29] Amicucci GL, Fiamingo F. Lightning risk to photovoltaic power generating systems. Prevention Today 2009;5:51–65.
[30] Singh PP, Singh S. Realistic generation cost of solar photovoltaic electricity. Renewable Energy 2010;35:563–9.